Optimum Size and Location of Distributed Generation and capacitor for Loss Reduction using different optimization technique in Power Distribution Network

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Abstract - ***The small scaled decentralized generating unit is known as distributed generation (DG). This decentralized or DG system is one of the modern techniques for solving the network problem i.e., power loss reduction, voltage profile improvement. This paper presents a comparison of three optimization technique i.e., PSO, GA and PSO+ABC for the placement of DG and capacitor in distribution system. The optimization is useful for the reduction of the real power loss and voltage profile improvement. The shunt capacitor is frequently used for reactive power compensation. The losses are major concern distribution system and these losses reduce by different technologies i.e., DG placement, capacitor placement, network reconfiguration. Finally in recent years are seen the capacitor is cheap source to reduce the losses and improve voltage profile. The effectives of these optimization techniques are tested on IEEE 33 bus test system under MATLAB software.***

Key Words*:* *Distributed generation, PSO, GA, PSO+ABC power loss minimization, capacitor placement.*

1.INTRODUCTION *(Size 11 , cambria font)*

In past years the shunt capacitor banks were placed in distribution system for reactive power compensation, it supports improving the voltage profile, reduce the power losses and improve the power factor [1]. The capacitor is connected in series parallel combination. Distribution generation is a small scale power generation or decentralized generating unit usually connected at load side in distribution system but the objective behind it is not new at all. When electricity demand increase at consumer level then transmission capacity of transmission line is also increase. It is mandatory to build a certain capacity of power plant at load centre and power grid. So as to reduce the power losses enhance the system stability. In today world, the DG technologies are developing swiftly and it is an attractive area in energy research direction. The total power delivered to the load side has been calculated according to total power generation and power loss in transmission system. Due to low voltage and high current in distribution system, the largest power losses are occur and they goes up to 5-13% of the total power generation. The capacitor placement and DG installation are two methods for loss reduction and voltage profile enhancement in distribution system. The PSO, GA and PSO+ABC are three meta-heuristic techniques. These techniques used in placement of DG and capacitor for power loss reduction. The GA optimization tool has been employed to solve different problem of DG and capacitor placement.

The author [4] suggested minimization of power loss, find optimal size and location of DG unit by using different techniques. The author of [6] discussed the optimal location of DG by using PSO and AI techniques and in [5] PSO is applied on three different of DG to determine optimal size and location. GA technique has been applied for loss minimization with optimal size of DG and capacitor [3]. In [9] the author describes the optimal location and size of different DG by using ABC technique for loss reduction.

The goal of PSO, GA and PSO+ABC method is to determine the best optimal location, size of capacitor and DG at that instant power loss is also minimize by increasing voltage profile. This paper contains following section are: section II describe mathematical problem formulation of power flow. In section III and IV brief description of PSO and GA. In section 5th the simulation result of three techniques is described.

2. PROBLEM FORMULATION

This section contains mathematically problem formulation of power flow. The real and reactive power loss is calculated by "exact loss formula"[2]. Load flow technique is used to find the accuracy, effectiveness for finding the exact solution.

The real and reactive power loss in power system is given as [7]

$$P_L=\sum_{i=1}^{n}\sum_{j=1}^{n}[\alpha_{ij}\left(P_iP_j+Q_iQ_j\right)+\beta_{ij}(Q_iP_j-P_iQ_j)] \quad (1)$$

Where

$\alpha_{ij}=r_{ij}/V_iV_j\cos(\delta_I-\delta_j$ $\quad \beta_{Ij}=r_{ij}/V_iV_j\sin(\delta_i-\delta_j)$

Here

$r_{ij}+x_{ij}=z_{ij}$ ith element of impedance matrix

$V_i\delta_i$ complex voltage at ith bus

P_i & P_j real power inject at ith and jth bus
N Total number of buses

At optimal location of DG the active and reactive power injected at that bus(i) are given by (2) and (3)

$$P_i = P_{DGi} - P_{Di} \quad (2)$$

$$Q_i = Q_{DGi} - Q_{Di} = \alpha P_{DGi} Q_i \quad (3)$$

Q_{DGI} is the reactive power output of DG is given in equation (3)
$Q_{DGi}=aP_{DGi}$
Where a is
$a=(sign)\tan(\cos^{-1}(PF_{DG}))$
in which
sign +1 is for: DG injecting reactive power
sign -1 is for: DG consuming reactive power

By substituting (2) and (3) in (1) the active power loss is

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}[\alpha_{ij}[(P_{DGi} - P_{Di})P_j + (aP_{DGi} - Q_{Di})Q_j] + \beta_{ij}[(aP_{DGi} - Q_{Di})P_j - (P_{DGi} - P_{Di})Q_j)] \quad (4)$$

Partial derivation of equation (4) w.r.t. injected real power from DG is equal to the zero then the system will give minimum active power loss. Here α and β are the loss coefficient. When DG install α and β will change and it depend on voltage and angle.
From equation (4)

$$\frac{\partial P_L}{\partial P_{DGi}} = 2\sum_{i=1}^{N}[\alpha_{IJ}(P_j + aQ_j) + \beta_{ij}(aP_j - Q_j)] = 0 \quad (5)$$

Let

$$X_{xi} = \sum_{j=1}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j)$$

$$Y_{yi} = \sum_{j=1}^{N}(\alpha_{ij}Q_j + \beta_{ij}P_j) \quad (6)$$

From equation (5) and (6)

$$\alpha_{ii}(P_{DGi} - P_D + a^2P_{DGi} - aQ_{Di}) + \beta_{ii}(Q_{Di} - aP_{Di}) + X_i + aY_i = 0 \quad (7)$$

From equation (7)
Optimal size of DG at each bus for minimization of loss can be written as

$$P_{DGi} = \frac{\alpha_{ii}(P_{Di} + aQ_{Di}) + \beta_{ii}(aP_{Di} - Q_{Di}) - X_i - aY_i}{a^2\alpha_{ii} + \alpha_{ii}} \quad (8)$$

DG Types

DG are categorized in four group based on active and reactive power

TYPE 1:- DG is capable of injecting active power like PV array, micro turbine, fuel cells etc.
The power factor of this type of DG is unity (PF=1, a=0)

TYPE 2:- DG is capable to produce reactive power like synchronous condenser. The power factor of this type of DG is zero (PF=0, a=∞)

TYPE 3:- DG is capable to inject active power but consume reactive power (sign -1) (e.g., induction generator) ($0<PF_{DG}<1$)

TYPE 4:- DG is capable to inject active or reactive power (sign +1) (e.g., synchronous generator, diesel generator) ($0<PF_{DG}<1$)

3. PARTICLE SWARM OPTIMIZATION

The PSO method is a population based and described the social behaviors of bird flocking or fish schooling for food. In PSO technique each particle move in a space and find g_{best} and p_{best} . James Kennedy and Rassel Eberhart in 1995 developed a population base particle swarm optimization [8].
The position and velocity of particle is

$$V_i^{K+1} = wV_i^K + C_1R_1(P_{besti} - S_i^K) + C_2R_2(G_{besti} - S_i^K) \quad (1)$$

$$S_i^{K+1} = S_i^K + V_i^{K+1} \quad (2)$$

Where

C_1 C_2:- are two positive constant

R_1 R_2:- arbitrary quantities between 0 and 1

W:- inertia weight

V_i^K :- velocity of i particle at iteration K

V_i^{K+1}:- reformed particle velocity of i

S_i^K:- recent position of particle I at iteration K

S_i^{K+1} :- improved position of particle i

P_{besti}:- individual best of particle i

G_{besti}:- global best of particle i

In this research the following inertia weight is used

$$W_i = W_{max} - \frac{W_{max} - W_{min}}{K_{max}} \times K$$

Where

W_{max} and W_{min} are maximum and minimum inertia weight

K and K_{max} are current and maximum iteration

PSO Algorithms:-
The PSO algorithm for solving the DG allocation problem can be summarized as follows:
1) Set the value of input line and bus data.
2) Calculate the loss using Newton-Raphson load flow Method.
3) Randomly initialize a population of particles with random Positions and velocities. Set the iteration k=0.
4) Compute the value of objective function.
5) For each particle, if the bus voltage is within the limits, Calculate the total loss using equation (6). Otherwise, the Particle is infeasible.
6) Compare each particle's objective value with the P_{best}. If the objective value is smaller than P_{best}, set this value as the current P_{best}.
7) Choose the particle associated with the minimum P_{best} of all particles, and set the value of this P_{best} as current G_{best}.
8) Update the velocity and position of particles using equation (10) and (11) respectively.
9) Set the index k=k+1 and repeat steps 4-8 until the maximum number of iteration number is reached.
10) Print out the solution. The best position includes the location and size of DG, and the related fitness value representing the minimum total real power loss

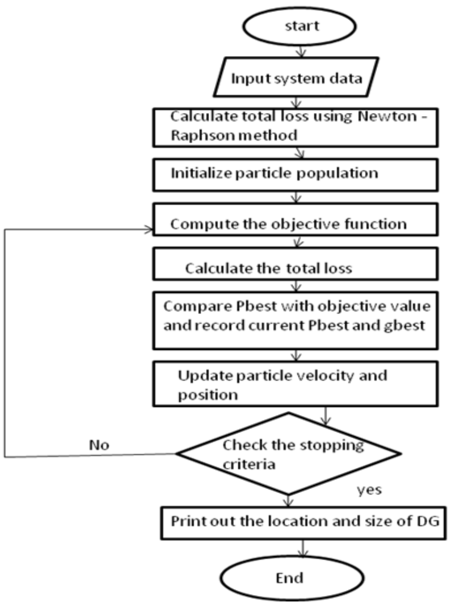

Fig. 1. PSO computational procedure

4. GENETIC ALGORITHM

The aim of optimization technique is improvement. GA optimization technique is suitable to solve the non linear problem of power system. GA used some operators like selection, mutation and crossover. A new and improved population is generated from old one by applying genetic operator. Selection process can be carried out in different way. Parents are selected to produce offspring. GA operators with a set of string and this binary set of string are called population. The GA operators applied on string and produce a new population by old one.
Steps for genetic algorithm:-

1. Create random population of n chromosomes.
2. Find the fitness of each chromosome in the population.
3. New population:
   a) Selection-it is based on the fitness function.
   b) Recombination-cross-over chromosomes
   c) Mutation-mutate chromosomes
4. Acceptation: accept or reject the new one
5. Replace the old population by new.
6. Test for problem standard
7. Carry on with step 2-5 until the standard is fulfilled.

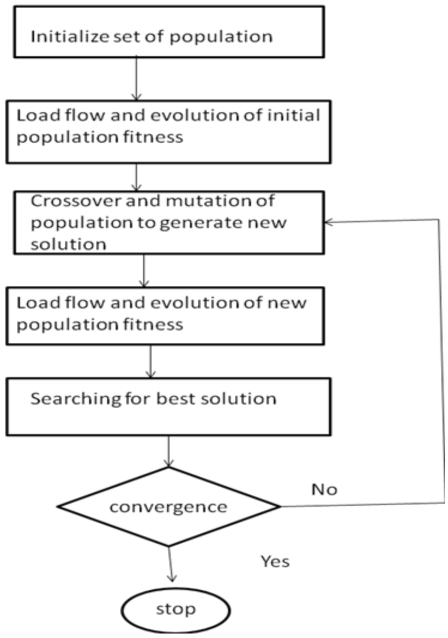

Fig 2- GA algorithm for DG placement

5. ARTIFICIAL BEE COLONY

The algorithm of artificial bee colony is developed from the behavior of the real honey bees. The ABC technique was developed in 2005 by karaboga. Furthermore, the ABC optimization technique was compared with the other optimization technique like as differential evaluation (DE), genetic algorithm (GA), particle swarm optimization (PSO) and evolutionary algorithm [9]. The artificial bee colony is a Meta heuristic method for solving multidimensional optimization problem.
Honey bee consist three types of bees:-employed bee, onlooker bee and scout bee [10]

Employed bees:-
The number of employed bee is equal to the food source and they go to their food source around the hive and then come back to the hive. They share the information about the food source with the other bees in the hive.

Onlooker bees:-
They watch the dance of various employed bees and choose the food source depending upon dance.

Scout bees:-
The food source of employed bees has been abandoned becomes a scout and searching for the new food source.

The probability of selecting food source by onlooker bee is calculated as

$$P_i = \frac{fitness_i}{\sum_{i=1}^{n} fitness_i}$$

Here fitness is the fitness value of the i solution and n is the total number of food source solution. The onlooker bees select their food source and generate neighbor's food source i+1 position. The food source of onlooker bees is equal to the half of the colony size.

Main code of ABC algorithm

1. Initialization
2. Evaluation
3. Cycle=1
4. Repeat
5. Employed bee phase
6. Calculate probability for onlooker bee
7. Onlooker bee phase
8. Scout bee phase
9. Obtained best solution
10. Cycle=cycle+1
11. Until cycle=maximum cycle number

6. RESULTS

When capacitor is place in distribution system the voltage profile is improve. The power loss get reduce after the placement of DG and capacitor and tested on IEEE 33 bus test system. In both optimization techniques the result is obtained at 400 runs in MATLAB software. The data for this paper is obtained from load flow program in MATLAB software and performed on laptop with Intel core ™ 2 and RAM of 2.00 GB.

Table -1: COMPARISION OF LOSSES BY THREE OPTIMIZATION TECHNIQUE GA, PSO AND PSO +ABC BEFORE OR AFTER PLACING THE CAPACITOR AND DG in IEEE 33 BUS TEST SYSTEM

Algorithm	Without capacitor losses	With capacitor losses	With capacitor+DG losses
GA	0.8204	0.6725	0.5930
PSO	0.8204	0.6724	0.5440
PSO &ABC	0.8204	0.6725	0.5346

Table -2: SIZE OF CAPACITOR AND DG IN IEEE 33 BUS TEST SYSTEMS BY USING THREE DIFFERENT OPTIMIZATION TECHNIQUES

Algorithm	Size of capacitor (mvar)	Size of DG (MW)	Capacitor location	DG location
GA	0.4431	0.424	30th bus	30th bus
PSO	0.4311	0.6507	30th bus	30th bus
PSO &ABC	0.4293	0.6615	30th bus	30th bus

When the capacitor is not placed in test system the losses are highest i.e, 0.8204 mw. This result is obtained by GA toolbox or PSO+ABC program with 20iteration and 20 population size. The best optimal size is obtained from GA toolbox is 0.4431 mvar for capacitor and 0.424 mw for DG. In all case power loss is reduce when capacitor and DG placed at 30 bus on IEEE 33 bus test system. In case of PSO the losses is reduced up to 0.5440 mw. When DG is placed then losses get reduced to 0.5346 mw by using PSO+ABC technique.

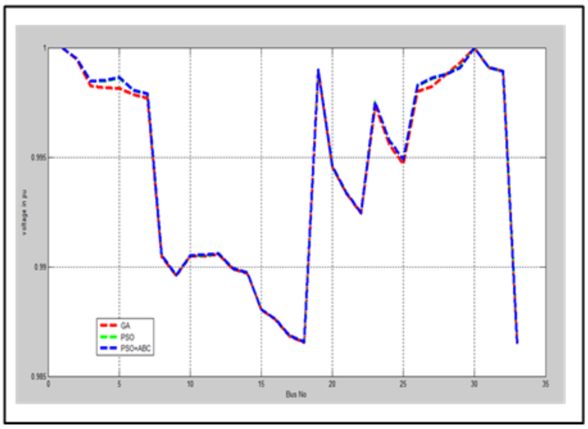

Fig 3-Voltage variation at different bus by using three different techniques.

This fig shows the voltage variation at different buses. The maximum voltage is 1 pu at 30 bus by using three different techniques. In these techniques the DG and capacitor is placed at 30 bus of different size. DG and capacitor increase the voltage profile at bus no 30. In case of PSO+ABC the voltage improvement is better than GA.

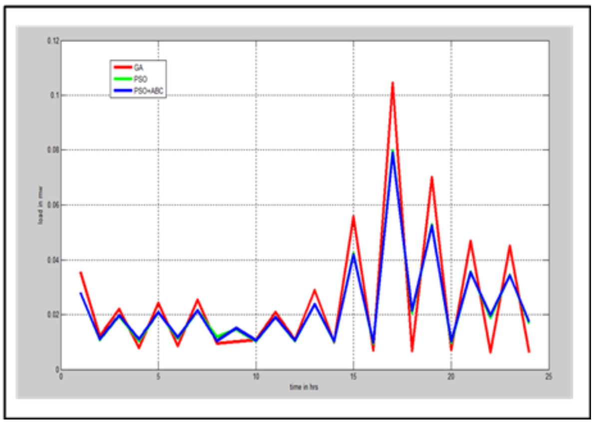

Fig 4- Monthly load variation by using three different techniques.

This fig shows the monthly load variation. The load variation is reducing in case of PSO+ABC as compare to GA. The maximum and minimum load in month of June and February but it reduces by PSO+ABC technique.

CONCLUSION

Three optimization techniques have been represented in this paper to find out the optimal sizes, locations of capacitor and DG in a distribution system at different variable load. IEEE-33 bus test system is used to verify the results of GA, PSO and PSO+ABC. Here with the help of genetic algorithm tool box and programming get the best location and size of capacitor and DG. This reduces the power losses effectively. The aim of this paper is to minimize the power losses and improve the voltage profile. All optimization technique tested in IEEE 33 bus system in MATLAB 2009.

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